Time Delay Between Gravitational Waves and Neutrino Burst From a Supernova Explosion: a Test for the Neutrino Mass

D. Fargion
Physics Department, Rome University 1
"La Sapienza",INFN, P.le A. Moro 2, 00185 Roma, Italy.
Daniele.Fargion@roma1.infn.it

ABSTRACT

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The gravitational collapse of a massive star is one of the most powerful mechanisms of simultaneous emission of neutrinos and gravitational waves. Almost all the present models for a supernova explosion predict a typical outburst of 10^{53} erg in its neutrino flow (namely electronic anti-neutrinos or neutrino pairs) with an average energy of 15 MeV for each neutrino. Most of these models predict that a relevant fraction of the neutrinos should be emitted by the supernova on a time scale of 0.1 s [1] or even in shorter pulses of $10^{-3}s$ [2]. The gravitational waves emitted in stellar collapse have the same characteristic time scale, since both processes are due to the same physical mechanism, i.e. a time of $10^{-3} \div 10^{-1}s$. Therefore, two signals, of different nature, originated within 0.1 s from the super nova explosion will be radiated in the outer space. If the neutrinos (as well as the gravitons) are massless particles, than the original interval (it any) between the two signals will be freezed forever. On the contrary, if the neutrinos have a mass, the time delay will increase during the propagation because of the slower velocity of the neutrinos with respect to the massless gravitons: namely for a neutrino mass $m_\nu = 15\eta eV$ ($\eta \sim 1$) , with an emission energy $E_\nu = 15MeV$, and for a source (the supernova) located in our Galaxy at a distance $L = 10kpc$ from us, the time delay between the two signals detected on the Earth will increase by a factor

$$\Delta\tau \simeq \frac{L}{2c}\left(\frac{m_\nu}{E_\nu}\right)^2 = 0.5\ \eta^2\ s \qquad (1)$$

For extra-galactic sources at $L = 10^2 \div 10^3$ kpc the delay will be $\Delta\tau \simeq (5 \div 50)\ \eta^2\ s$. Since the sensibility of the present neutrino detectors and gravitational antennae permit us to observe supernova events within our Galaxy (and in the near future even within near group of galaxies) [3],[4] since their time accuracy is roughly $10^{-3}s$, the time delay measure is possible and it could give an estimate of the neutrino mass. No appreciable time delay will infer strong limits to the neutrino mass. Analogous arguments for a time correlation between optical events [4] and neutrino burst or neutrino-neutrino bursts [5] at different energies

[1] J. SHRAMM: D. N. Proceedings of Neutrino '79 (Bergen, 1979), p. 503

[2] C. CASTAGNOLI, P. GALEOTTI and O. SAAVERDRA: Astophys. Space Sci., **55 , 511 (1978)**

[3] E. AMALDI and G. PIZZELLA: Astrofisica e cosmologia, gravitazione, quanti e relativit (Firenze, 1979), p. 283

[4] J. LEARNED and D. EICHLER: Scientific American (February 1981), p. 104. C)

[5] N. CABIBBO: Astrophysics and Elementary Particles, Common Problems (Roma, 1980), p. 229.

(originated by a supernova explosion) seem to be, at the moment, less praticable or less conclusive.

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